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Failing Coastal Wood Infrastructure on the Great Lakes

Introduction

Many Great Lakes coastal communities, ports and harbors are protected from damaging storms, waves and ice by offshore and coastal structures. This critical waterfront infrastructure protects channel entrances used for both commercial and recreational navigation, interior harbor slips, public and private waterfront facilities (power generators, water intake and supply facilities and other commercial structures) as well as many marinas, beaches and private property shorelines.

Many larger harbor entrance structures were initially constructed and maintained by the U.S. Army Corps of Engineers. The majority of these structures were constructed 100 years ago or earlier, some as long ago as 1860.

Since they were first constructed, Great Lakes harbors have become less important for commercial shipping, but they have become extremely important for recreation. However, due to a lack of federal funding, maintenance of these structures has lagged and many are now in poor condition. Many of these failing structures are made partially or totally from wood. Failure of these structures would be catastrophic for the valuable Great Lakes coastal communities they protect. A 2010 study of U.S. and Canadian Great Lakes ports found that they support 227,000 jobs, contribute $14.1 billion in annual personal income, $33.5 billion in business revenue and $6.4 billion in local purchases.

Common Wood Structure/ Component Types

Many of the early harbor entrance breakwaters were constructed with an underwater timber crib base filled with rock. On top of the structure a cap of either stone or concrete was added as a superstructure above the water surface. Figure 1 shows a typical breakwater built with a timber crib foundation and a concrete cap on top. Figure 2 shows a schematic of a typical U.S. Army Corps of Engineers breakwater section. Other designs incorporate timber pilings with a concrete cap.

Timber is also attached to slip walls in a horizontal fashion to protect against vessel wear and to absorb vessel impacts. Timber walls are also common. This design often incorporates vertical steel H-piles with wood timbers placed horizontally between the vertical steel piles. Figure 3 shows a typical timber wall design (often called a soldier pile wall).

Figure 1: A typical U.S. Army Corps of Engineers breakwater section (Gene Clark/UW Sea Grant Institute).

Figure 3: Timber soldier pile wall (Gene Clark/UW Sea Grant Institute).

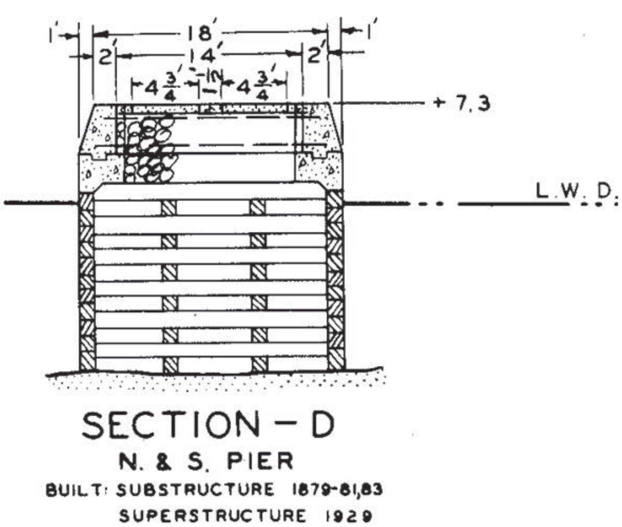

Figure 2: Section drawing of a U.S. Army Corps of Engineers breakwater (U.S. Army Corps of Engineers).

Wood Structure Failure Mechanisms

When Great Lakes timber structures remain underwater, the timber can last indefinitely. However, when exposed to air, the timber will begin to rot. Although wood borers can cause damage in marine environments, there are no freshwater wood borers. Failing timber cribs have been observed at many older ports and harbors as the timber core sections begin to decay and slump, bringing the superstructure down with it. Several Great Lakes locations have experienced complete failure of the structures due to deteriorating timbers. This problem has increased in the recent decades due to lower-than-average water levels in the Great Lakes over the last several years.

Timber pilings will also rot when exposed to constant cycles of wet and dry. Figure 4 shows a timber crib wall with significant rot, and Figure 5 shows timber pilings rotting near the water surface. Once the timber begins to rot, the stone filling the crib- or pile-supported structure can spill out and disperse into the lake alongside the structure. Figure 6 shows an example of the loss of interior stone from an underwater timber crib.

Poorly designed timber crib foundations have also caused structure failure. Wave action at the base of these structures scours the foundation material away, causing the timber crib to settle. This scour can also be due to low water conditions with additional ship thruster action contributing to structural deterioration. Figure 7 shows a timber crib section that has failed due to a poor foundation.

Figure 4: Timber structure rot (Gene Clark/UW Sea Grant Institute).

Figure 6: Timber crib with interior rock loss (Bill Brose–SmithGroupJJR).

Figure 5: Timber piling rotting at the water surface (Larry Ryan–Baird).

Figure 7: Timber crib settlement failure (Gene Clark/UW Sea Grant Institute).

Timber wear or abrasion due to ice or ship damage are other common conditions that can lead to timber failure. While this type of failure does not often compromise the structure behind the timber, it can cause significant damage to the vessel attempting to moor alongside the vertical face of the structure. Figure 8 shows abrasion damage to a timber abrasion protection section.

Another reason more timber crib structures have failed recently is that the steel pins used to connect them have been corroding. (For more information, refer to the Wisconsin Sea Grant fact sheet "Accelerated Freshwater Harbor Corrosion," which is available in the Aquatic Sciences online publication store at http://aqua.wisc.edu/publications/PDFs/FreshwaterHarborCorrosion.pdf.) Once these steel pins corrode, the timber cribs start to come apart and fail similarly to those with rot issues. Figure 9 shows a corroded steel pin. Note that steel remains where the pin would be in the timber, but it is corroded where the pin would exit the crib and cross the open stone-filled interior of the crib.

Figure 8: Timber ice abrasion damage (Gene Clark/UW Sea Grant Institute).

Figure 9: Corroded timber crib connection steel pin (Gene Clark/UW Sea Grant Institute).

Repair Methods

Repair methods for failing timber structures depend upon the type of structure and whether the damage is located near the existing waterline or if it continues down to the base of the structure. The method of repair would also vary depending upon the degree of timber degradation.

When the timber deterioration is near the water surface, the failed timber can be removed and a new structure attached to the remaining crib top near the water level. This structure could be a new timber crib or steel H-beams attached to the existing crib, with either new timber beams or precast concrete panels placed between the vertical beams (soldier pile walls). See Figure 10 for an example of a new concrete wall constructed on top of a failed timber crib.

Figure 10: New wall constructed on top of failed timber crib (Chad Scott–AMI Consulting Engineers).

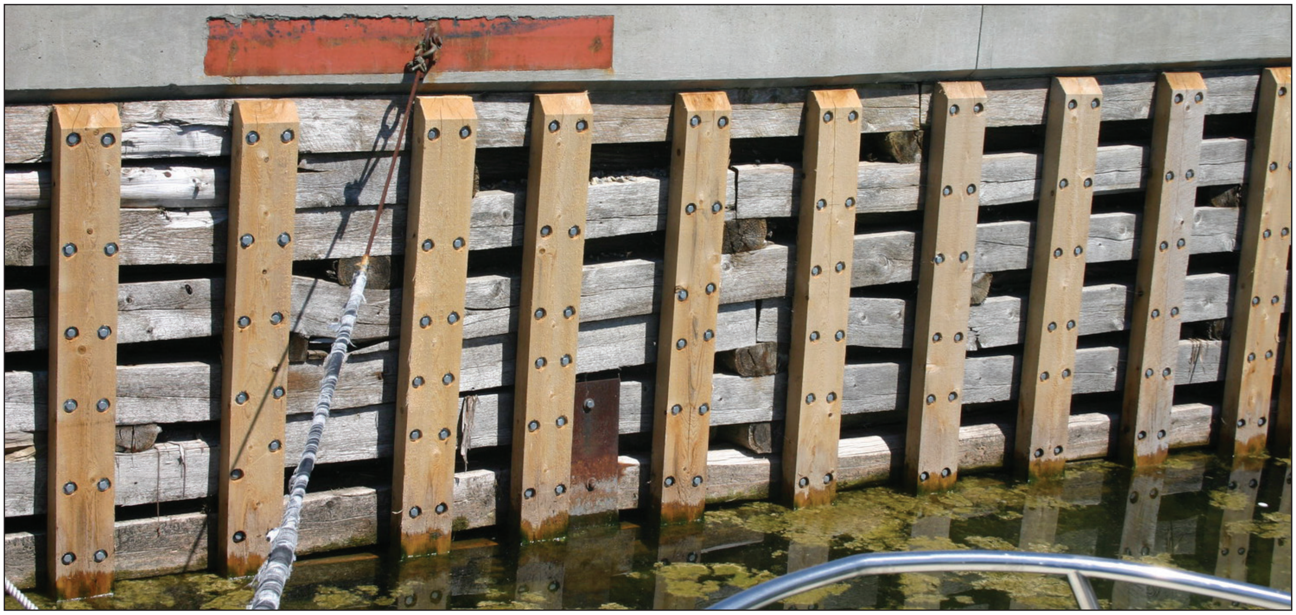

Figure 11: A failed timber reinforcement section (Larry Ryan–Baird).

Figure 12: A new wall in front of a failed timber structure (Chad Scott–AMI Consulting Engineers).

If the timber has only slightly deteriorated, the existing timber can be reinforced with new timber members if easy access is possible and there is no danger to the remaining section. Figure 11 shows vertical reinforcing added to an existing timber crib.

For crib or timber wall structures that have suffered timber damage so severe that complete replacement of the failed structure is required, potential solutions depend on the type of structure. Options include a complete new facing that consists of a steel H-piling driven in front of the failing crib or wood wall from the lake bottom to above the existing surface with timber beams or precast concrete panels. The front facing could also be constructed of steel sheet pile with a fill of stone between the old and new structure. Figure 12 shows a new steel and concrete wall built in front of a failing timber structure.

Wood pilings that have not rotted too severely could be encapsulated with jackets—for example, using steel pipe halves bolted together around the damaged sections, fiberglass shells filled with either a concrete or epoxy grout, or high-density polyethylene wraps. See Figures 13, 14 and 15 for examples of jackets used on steel H- and pipe-piles. They are representative of timber piling protection as well.

Conclusions

Any Great Lakes timber structure repair method requires the services of a professional engineer with significant experience in Great Lakes structure inspection and design. Often the services of a professional diver are required for adequate structure inspection.

Currently, the American Society of Civil Engineers is completing a new *Waterfront Facility Inspection Manual* as well as a new *Timber Waterfront Manual*. Both will provide useful information for the inspection, planning and design of deteriorating Great Lake timber structure repair or replacement.

Figure 13: Steel jacket option shown on steel pile (Gene Clark/UW Sea Grant Institute).

Figure 15: High-density polyethylene jacket option shown on steel pile (Gene Clark/UW Sea Grant Institute

Figure 14: Fiberglass jacket option shown on steel H-pile (Gene Clark/UW Sea Grant Institute).

For Additional Information

- *ASCE Underwater Investigations Standard Practice Manual No. 101*, 2001.
- *The Repair, Maintenance and Rehabilitation (REMR) Notebook*, U.S. Army Corps of Engineers, 1991.
- *Best-Practice Inspection Guidelines for Great Lakes Port, Harbor and Marina Structures*, University of Wisconsin Sea Grant Fact Sheet, 2012.

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